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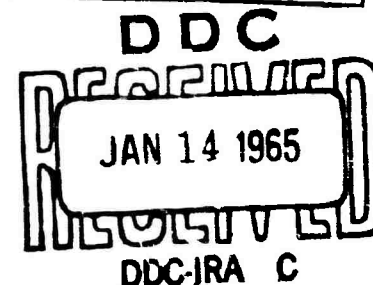
Title: The Study of the Origin and Propagation of Disturbances
          in the Burning of Solid Propellants

Subject: Quarterly Narrative Progress Report, No. 11,
          SRI Project PRU-2770, covering the Period July 1 through
          September 30, 1961

The most severe limitations in the accuracy and time resolution
of the instrumentation system (described in the previous quarterly
report, June 30, 1961) were due to factors inherent in the operation of
the oscilloscope and the reading of the film on which the oscilloscope
traces are recorded. Much of the work of the current period has been
devoted to the development of a recording system which will allow the
reading of the (filtered) pressure signal at accurate time intervals of
as little as 10μ sec, to an accuracy of about 0.5 per cent of peak
pressure.

The principal electronic components of this recording system
are a Tektronix 535-H type oscilloscope with a Type G differential
preamplifier, a separate Tektronix delay circuit (comprised of units
160A, 162, 163), a Tektronix Type 181 time mark generator and a
blocking oscillator frequency divider. The blocking oscillator is fed
by pulses at 10μ sec intervals from the time mark generator and has
two outputs: output 1 produces pulses at 10, 20, 30, 40 or 50μ sec

intervals, depending on the setting of a switch; output 2 produces a pulse for every fifth pulse produced by output 1. Both outputs are fed into the Z-axis input of the oscilloscope through a diode network in such a way that the oscilloscope trace is displayed as a series of dots at 10 to 50μ sec intervals, with every fifth dot brightened. The maximum possible time resolution has been increased by (1) the use of an H-modified oscilloscope which produces a very fine trace by virtue of the 12 kv accelerating potential used in the cathode ray tube and (2) the use of an extra delay circuit which allows the incident and reflected pulses to be displayed in two separate sweeps, with distinct base lines. For the pulses currently employed, the maximum allowable sweep speed has thus been increased from 700μ sec/cm to about 250μ sec /cm; at this latter rate, the fine trace allows the resolution of dots at 10μ sec intervals.

To measure the amplitude, a photographic technique has been applied. The trace is photographed without a graticule on Polaroid film. An overlay about 60 lines/cm (white lines on transparent film, every tenth line marked by breaks) is placed over the Polaroid film and aligned with the base line of the incident pulse. This arrangement, held in a simple die, is then rephotographed on 35 mm film. The process is repeated with the reflected pulse. The overlay is made by photographic reduction of a large Mylar-base master which has been ruled accurately.

The resulting 35 mm film may then be printed to any convenient size, or read directly by use of a microfilm viewer. Optical distortion is not a problem since it does not affect the decision whether a given dot lies on a given line. Preliminary results indicate that the films can be read very quickly.

To calibrate the vertical deflection, the saw-tooth from the internal delay circuit is displayed on the scope face. This saw-tooth is extremely linear in the central portion of the upsweep (this was verified by an independent calibration with a scaler). By suitably adjusting the frequency and amplitude of the saw-tooth and the

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sweep-rate, it is possible to obtain several series of dots across the scope face, each series lying along a nearly vertical line. The difference in vertical deflection between any two adjacent dots corresponds to a constant voltage increment. Although we have found a definite non-linearity (at least partly due to the preamp) in the vertical deflection, it appears to be independent of the horizontal position. The calibration procedure involves taking a picture of the saw-tooth display with the same preamp setting as is used in the recording of the pressure pulse, and reading the position of successive points with the use of the same overlay technique as described above. Two fiduciary readings are taken, viz. the distance of the pulse base line and of the lowest saw-tooth point from the bottom of the picture. A simple machine program has been developed which takes a deck of cards containing the uncalibrated pressure-time information and puts out a new deck which has been corrected for the non-linearity in the deflection.

The evaluation of the pulse method for measuring the acoustic admittance will continue along the lines indicated in our previous report (No. 10, June 30, 1961). The preparation of a series of standard samples will now be undertaken for low admittance materials. For this purpose the employment of sandpaper of various grades cemented to aluminum blocks is being considered.

Plans are being initiated for the eventual admittance testing of burning propellants. In the very near future tests will be begun to assist in the choice of a propellant formulation which will be suitable for use as a working material in the further development and perfection of the pulse technique. Some features desired are low flame temperature, low burning rate, good ignitability, the absence of solid combustion products, a smooth surface during burning and relative ease in the preparation of reproducible samples.
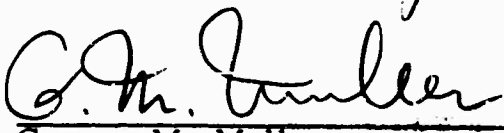
Before undertaking admittance measurements on burning propellants cold systems with gas flow will be examined. This is desirable to assist in the design of the eventual combustion apparatus and also possibly to furnish standards for measurements on burning

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propellants. One of the problems envisioned is the protection of the delicate transducer element from the hot and possibly corrosive combustion gases. One procedure considered involves the continual submergence of the transducer in a cold air stream. The effect of the coolant air stream upon the measurement can be examined in a cold model where the hot combustion gas and the cold air are replaced by two gases which continue to bear the same, or nearly the same, density ratio and ρc ratio (ρ = density, c = sonic velocity) to one another. A gas combination which will be employed in such a model will probably be air (to represent the hot combustion gas) and "Freon-114" (to represent the cold air). In principle helium-air could be used to model the system (combustion gas-cold air), but it is impractical in shock tubes of the size considered ($1\frac{1}{2}$ in. inside diameter) to match the helium volumetric flow rate with the large flow rate of the combustion gas.

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